CMSC 330: Organization of Programming Languages

Ruby Regular Expressions

String Processing in Ruby

- Earlier, we motivated scripting languages using a popular application of them: string processing
- The Ruby String class provides many useful methods for manipulating strings
  - Concatenating them, grabbing substrings, searching in them, etc.
- A key feature in Ruby is its native support for regular expressions
  - Very useful for parsing and searching
  - First gained popularity in Perl

String Operations in Ruby

- "hello".index("l", 0)
  - Return index of the first occurrence of string in s, starting at n
- "hello".sub("h", "j")
  - Replace first occurrence of "h" by "j" in string
  - Use gsub ("global" sub) to replace all occurrences
- "r1\tr2\t\tr3".split("\t")
  - Return array of substrings delimited by tab

- Consider these three examples again
  - All involve searching in a string for a certain pattern
  - What if we want to find more complicated patterns?
    - Find first occurrence of "a" or "b"
    - Split string at tabs, spaces, and newlines

Regular Expressions

- A way of describing patterns or sets of strings
  - Searching and matching
  - Formally describing strings
    - The symbols (lexemes or tokens) that make up a language
- Common to lots of languages and tools
  - awk, sed, perl, grep, Java, OCaml, C libraries, etc.
    - Popularized (and made fast) as a language feature in Perl
- Based on some really elegant theory
  - Future lecture

Example Regular Expressions in Ruby

- /Ruby/
  - Matches exactly the string "Ruby"
  - Regular expressions can be delimited by /'s
  - Use \ to escape /'s in regular expressions
- /(Ruby|OCaml|Java)/
  - Matches either "Ruby", "OCaml", or "Java"
- /(Ruby|Regular)/ or /R(uby|egular)/
  - Matches either "Ruby" or "Regular"
  - Use ( )'s for grouping; use \ to escape ( )'s

Using Regular Expressions

- Regular expressions are instances of Regexp
  - We'll see use of a Regexp.new later
- Basic matching using =~ method of String

```
line = gets                     # read line from standard input
if line =~ /Ruby/ then          # returns nil if not found
  puts "Found Ruby"
end
```

- Can use regular expressions in index, search, etc.

```
offset = line.index(/(MAX|MIN)/)    # search starting from 0
line.sub(/(Perl|Python)/, "Ruby")   # replace
line.split(/(\t|\n| )/)             # split at tab, space,
                                    # newline
```

Repetition in Regular Expressions

- /(Ruby)*/
  - {"", "Ruby", "RubyRuby", "RubyRubyRuby", ...}
  - * means *zero or more occurrences*
- /Ruby+/
  - {"Ruby", "Rubyy", "Rubyyy", ... }
  - + means *one or more occurrence*
  - so /e+/ is the same as /ee*/
- /(Ruby)?/
  - {"", "Ruby"}
  - ? means *optional*, i.e., zero or one occurrence

Repetition in Regular Expressions

- /(Ruby){3}/
  - {“RubyRubyRuby”}
  - {x} means repeat the search for exactly x occurrences
- /(Ruby){3,}/
  - {“RubyRubyRuby”, “RubyRubyRubyRuby”, …}
  - {x,} means repeat the search for at least x occurrences
- /(Ruby){3, 5}/
  - {“RubyRubyRuby”, “RubyRubyRubyRuby”, “RubyRubyRubyRubyRuby”}
  - {x, y} means repeat the search for at least x occurrences and at most y occurrences

Watch Out for Precedence

- /(Ruby)*/ means {"", "Ruby", "RubyRuby", ...}
- /Ruby*/ means {"Rub", "Ruby", "Rubyy", ...}
- In general
  - * {n} and + bind most tightly
  - Then concatenation (adjacency of regular expressions)
  - Then |
- Best to use parentheses to disambiguate
  - Note that parentheses have another use, to extract matches, as we'll see later

Character Classes

- /[abcd]/
  - {"a", "b", "c", "d"} (Can you write this another way?)
- /[a-zA-Z0-9]/
  - Any upper or lower case letter or digit
- /[^0-9]/
  - Any character except 0-9 (the ^ is like not and must come first)
- /[\t\n]/
  - Tab, newline or space
- /[a-zA-Z_\$][a-zA-Z_\$0-9]*/
  - Java identifiers ($ escaped...see next slide)

Special Characters

.	any character
^	beginning of line
$	end of line
\$	just a $
\d	digit, [0-9]
\s	whitespace, [\t\r\n\f\s]
\w	word character, [A-Za-z0-9_]
\D	non-digit, [^0-9]
\S	non-space, [^\t\r\n\f\s]
\W	non-word, [^A-Za-z0-9_]

Using /^pattern$/ ensures entire string/line must match pattern

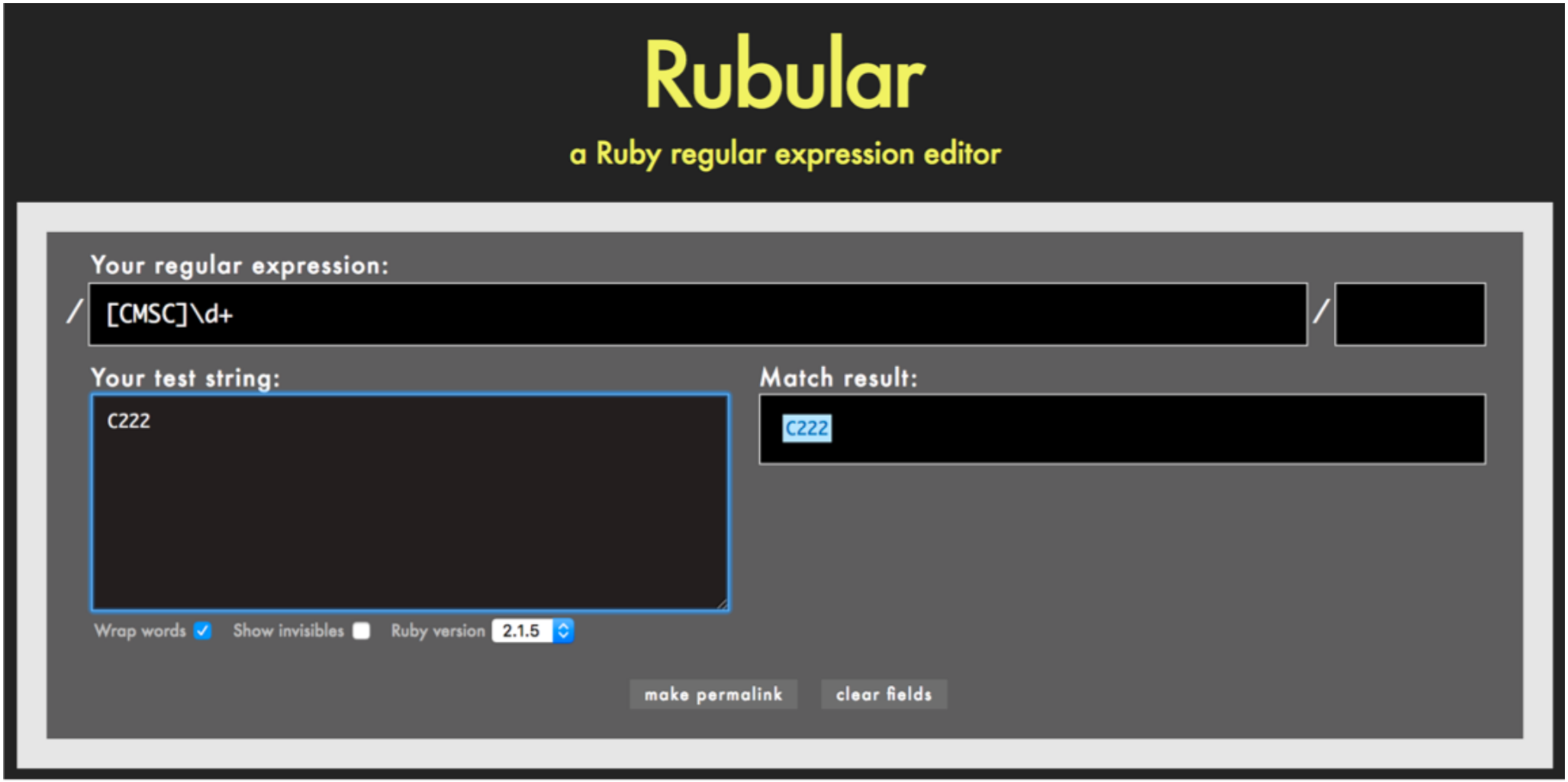
Potential Character Class Confusions

- ^
  - Inside character classes: *not*
  - Outside character classes: beginning of line
- [ ]
  - Inside regular expressions: character class
  - Outside regular expressions: array
    - Note: [a-z] does not make a valid array
- ( )
  - Inside character classes: literal characters ( )
    - Note /(0..2)/ does not mean 012
  - Outside character classes: used for grouping
- –
  - Inside character classes: range (e.g., a to z given by [a-z])
  - Outside character classes: subtraction

Summary

- Let *re* represents an arbitrary pattern; then:
  - /*re*/ – matches regexp *re*
  - /(*re*$_1$|*re*$_2$)/ – match either *re*$_1$ or *re*$_2$
  - /(*re*)*/ – match 0 or more occurrences of *re*
  - /(*re*)+/ – match 1 or more occurrences of *re*
  - /(*re*)?/ – match 0 or 1 occurrences of *re*
  - /(*re*){2}/ – match exactly two occurrences of *re*
  - /[a-z]/ – same as (a|b|c|...|z)
  - / [^0-9]/ – match any character that is not 0, 1, etc.
  - ^, $ – match start or end of string

Try out regexps at rubular.com



Regular Expression Practice

- Make Ruby regular expressions representing
  - All lines beginning with a or b `/^(a|b)/`
  - All lines containing at least two (only alphabetic) words separated by white-space `/[a-zA-Z]+\s+[a-zA-Z]+/`
  - All lines where a and b alternate and appear at least once `/^((ab)+ a?)|((ba)+ b?)$/`
  - An expression which would match both of these lines (but not radically different ones)
    - CMSC330: Organization of Programming Languages: Fall 2016
    - CMSC351: Algorithms: Fall 2016

Quiz 1

How many different strings could this regex match?

```
/^Hello. Anyone awake?$/
```

A. 1
B. 2
C. 4
D. More than 4

Quiz 1

How many different strings could this regex match?

```
/^Hello. Anyone awake?$/
```

∈ or nothing

Matches any character

A. 1
B. 2
C. 4
D. More than 4

Quiz 2

Which regex is not equivalent to the others?

A. `^[computer]$`
B. `^(c|o|m|p|u|t|e|r)$`
C. `^([comp]|[uter])$`
D. `^c?o?m?p?u?t?e?r?$`

Quiz 2

Which regex is not equivalent to the others?

A. `^[computer]$`
B. `^(c|o|m|p|u|t|e|r)$`
C. `^([comp]|[uter])$`
D. `^c?o?m?p?u?t?e?r?$`

Quiz 3

Which string does not match the regex?

```
/[a-z]{4}\d{3}/
```

A. "cmsc\d\d\d"
B. "cmsc330"
C. "hellocmsc330"
D. "cmsc330world"

Quiz 3

Which string does not match the regex?

*Recall that without ^ and $, a regex will match any **sub**string*

```
/[a-z]{4}\d{3}/
```

A. "cmsc\d\d\d"
B. "cmsc330"
C. "hellocmsc330"
D. "cmsc330world"

Extracting Substrings based on R.E.'s Method 1: Back References

Two options to extract substrings based on R.E.'s:

- Use back references
  - Ruby remembers which strings matched the parenthesized parts of r.e.'s
  - These parts can be referred to using special variables called back references (named $1, $2,…)

Back Reference Example

- Extract information from a report

```
gets =~ /^Min: (\d+)  Max: (\d+)$/
min, max = $1, $2
```

```
sets min = $1
 and max = $2
```

- Warning
  - Despite their names, $1 etc are local variables

```
def m(s)
  s =~ /(Foo)/
  puts $1    # prints Foo
end
m("Foo")
puts $1      # prints nil
```

Another Back Reference Example

- Warning 2
  - If another search is performed, all back references are reset to nil

```
gets =~ /(h)e(ll)o/
puts $1
puts $2
gets =~ /h(e)llo/
puts $1
puts $2
gets =~ /hello/
puts $1
```

```
hello
h
ll
hello
e
nil
hello
nil
```

Quiz 4

What is the output of the following code?

```
s = "help I'm stuck in a text editor"
s =~ /([A-Z]+)/
puts $1
```

A. help
B. I
C. I'm
D. I'm stuck in a text editor

Quiz 4

What is the output of the following code?

```
s = "help I'm stuck in a text editor"
s =~ /([A-Z]+)/
puts $1
```

A. help
B. I
C. I'm
D. I'm stuck in a text editor

Quiz 5

What is the output of the following code?

```
"Why was 6 afraid of 7?" =~ /\d\s(\w+).*(\d)/
puts $2
```

A. afraid
B. Why
C. 6
D. 7

Quiz 5

What is the output of the following code?

```
"Why was 6 afraid of 7?" =~ /\d\s(\w+).*(\d)/
puts $2
```

A. afraid
B. Why
C. 6
D. 7

Method 2: String.scan

- Also extracts substrings based on regular expressions
- Can optionally use parentheses in regular expression to affect how the extraction is done
- Has two forms that differ in what Ruby does with the matched substrings
  - The first form returns an array
  - The second form uses a code block
    - We'll see this later

First Form of the Scan Method

- *str*.scan(*regexp*)
  - If regexp doesn't contain any parenthesized subparts, returns an array of matches
    - An array of all the substrings of *str* which matched

```
s = "CMSC 330 Fall 2007"
s.scan(/\S+ \S+/)
# returns array ["CMSC 330", "Fall 2007"]
```

    - Note: these strings are chosen sequentially from as yet unmatched portions of the string, so while "330 Fall" *does* match the regular expression above, it is *not* returned since "330" has already been matched by a previous substring.

```
s.scan(/\S{2}/)
# => ["CM", "SC", "33", "Fa", "ll", "20", "07"]
```

First Form of the Scan Method (cont.)

- If regexp contains parenthesized subparts, returns an array of arrays
  - Each sub-array contains the parts of the string which matched one occurrence of the search

```
s = "CMSC 330 Fall 2007"
s.scan(/(\S+) (\S+)/)  # [["CMSC", "330"],
                       #  ["Fall", "2007"]]
```

  - Each sub-array has the same number of entries as the number of parenthesized subparts
  - All strings that matched the first part of the search (or $1 in back-reference terms) are located in the first position of each sub-array

Practice with Scan and Back-references

```
> ls -l
drwx------    2 sorelle  sorelle  4096 Feb 18 18:05 bin
-rw-------    1 sorelle  sorelle  674 Jun  1 15:27 calendar
drwx------    3 sorelle  sorelle  4096 May 11  2006 cmsc311
drwx------    2 sorelle  sorelle  4096 Jun  4 17:31 cmsc330
drwx------    1 sorelle  sorelle  4096 May 30 19:19 cmsc630
drwx------    1 sorelle  sorelle  4096 May 30 19:20 cmsc631
```

Extract just the file or directory name from a line using

- scan

```
name = line.scan(/\S+$/)   # ["bin"]
```

- back-references

```
if line =~ /(\S+$)/
      name = $1    # "bin"
end
```

Quiz 6

What is the output of the following code?

```
s = "Hello World"
t = s.scan(/\w{2}/).length
puts t
```

A. 3
B. 4
C. 5
D. 6

Quiz 6

What is the output of the following code?

```
s = "Hello World"
t = s.scan(/\w{2}/).length
puts t
```

A. 3
B. 4
C. 5
D. 6

Quiz 7

What is the output of the following code?

```
s = "To be, or not to be!"
a = s.scan(/(\S+) (\S+)/)
puts a.inspect
```

A. `["To","be,","or","not","to","be!"]`
B. `[["To","be,"],["or","not"],["to","be!"]]`
C. `["To","be,"]`
D. `["to","be!"]`

Quiz 7

What is the output of the following code?

```
s = "To be, or not to be!"
a = s.scan(/(\S+) (\S+)/)
puts a.inspect
```

A. `["To","be,","or","not","to","be!"]`
B. `[["To","be,"],["or","not"],["to","be!"]]`
C. `["To","be,"]`
D. `["to","be!"]`

Second Form of the Scan Method

- Can take a code block as an optional argument

- str.scan(regexp) { |match| block }
  - Applies the code block to each match
  - Short for str.scan(regexp).each { |match| block }
  - The regular expression can also contain parenthesized subparts

Example of Second Form of Scan

```
12  34  23
19  77  87
11  98  3
2   45  0
```

input file:
will be read line by line, but
column summation is desired

```
sum_a = sum_b = sum_c = 0
while (line = gets)
  line.scan(/(\d+)\s+(\d+)\s+(\d+)/) { |a,b,c|
    sum_a += a.to_i
    sum_b += b.to_i
    sum_c += c.to_i
  }
end
printf("Total: %d %d %d\n", sum_a, sum_b, sum_c)
```

converts the string
to an integer

Sums up three columns of numbers

Standard Library: File

- Lots of convenient methods for IO

```
File.new("file.txt", "rw")      # open for rw access
f.readline                      # reads the next line from a file
f.readlines                     # returns an array of all file lines
f.eof                           # return true if at end of file
f.close                         # close file
f << object                     # convert object to string and write to f
$stdin, $stdout, $stderr        # global variables for standard UNIX IO
```

  By default stdin reads from keyboard, and stdout and stderr both write to terminal

- File inherits some of these methods from IO

Exceptions

- Use begin...rescue...ensure...end
  - Like try...catch...finally in Java

```
begin
  f = File.open("test.txt", "r")
  while !f.eof
    line = f.readline
    puts line
  end
rescue Exception => e
  puts "Exception:" + e.to_s +
   " (class " + e.class.to_s + ")"
ensure
  f.close if f != nil
end
```

Class of exception to catch

Local name for exception

Always happens

Command Line Arguments

- Stored in predefined global constant ARGV

- Example
  - If
    - Invoke test.rb as “ruby test.rb a b c”
  - Then
    - ARGV[0] = “a”
    - ARGV[1] = “b”
    - ARGV[2] = “c”

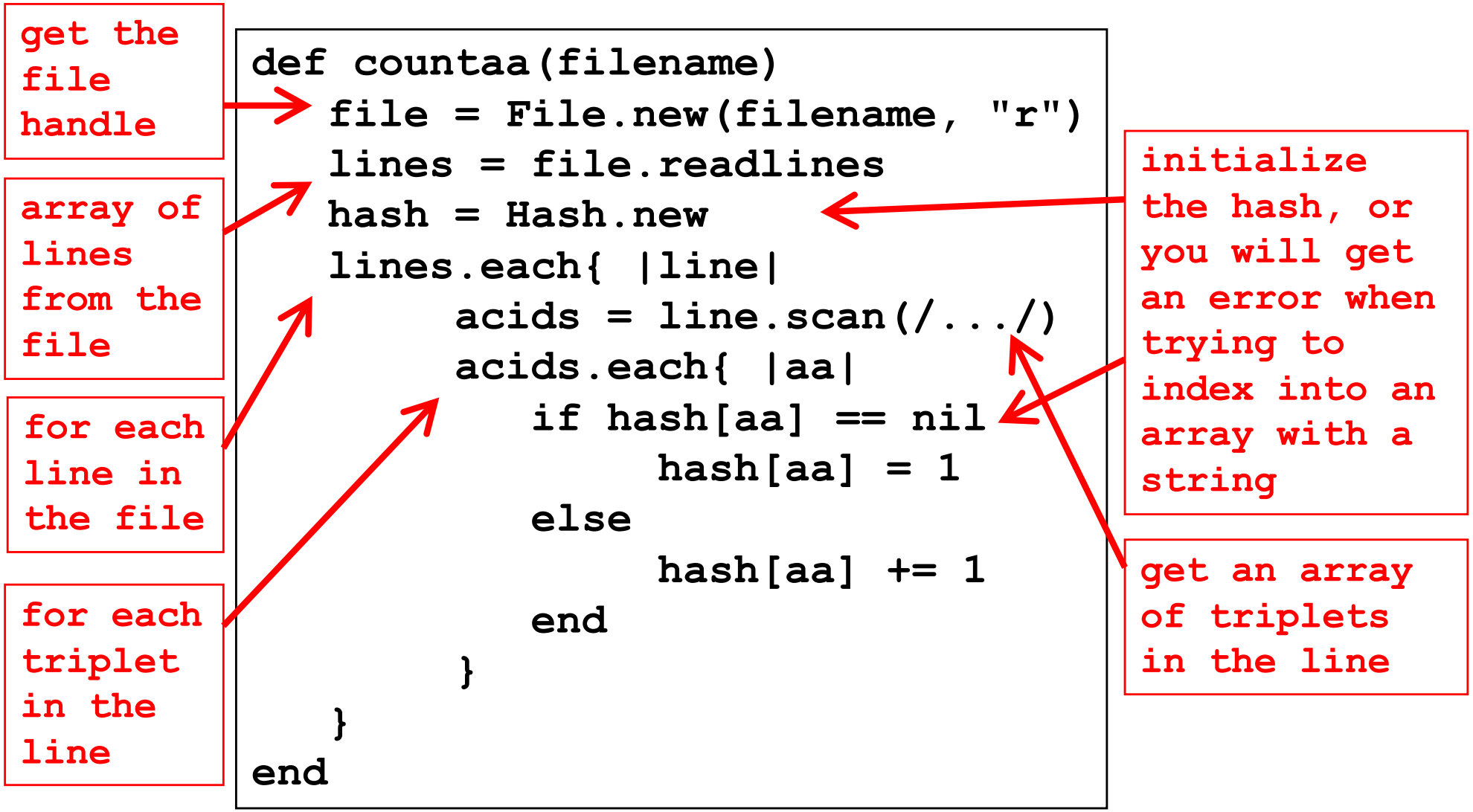
Practice: Amino Acid counting in DNA

Write a function that will take a filename and read through that file counting the number of times each group of three letters appears so these numbers can be accessed from a hash.

(assume: the number of chars per line is a multiple of 3)

```
gcggcattcagcacccgtatactgttaagcaatccagattttgtgtataacataccggc
catactgaagcattcattgaggctagcgctgataacagtagcgctaacaatggggaatg
tggcaatacggtgcgattactaagagccgggaccacacaccccgtaaggatggagcgtgg
taacataataatccgttcaagcagtgggcgaaggtggagatgttccagtaagaatagtgg
gggcctactacccatggtacataattaagagatcgtcaatcttgagacggtcaatggtac
cgagactatatcactcaactccggacgtatgcgcttactggtcacctcgttactgacgga
```

Practice: Amino Acid counting in DNA



Comparisons

- Sorting requires ability to compare two values
- Ruby comparison method <=>
  - -1 = less
  - 0 = equals
  - +1 = greater
- Examples
  - 3 <=> 4 returns -1
  - 4 <=> 3 returns +1
  - 3 <=> 3 returns 0

Sorting

- Two ways to sort an Array
  - Default sort (puts values in ascending order)
    - [2,5,1,3,4].sort # returns [1,2,3,4,5]
  - Custom sort (based on value returned by code block}
    - [2,5,1,3,4].sort { |x,y| y <=> x } # returns [5,4,3,2,1]
    - Where -1 = less, 0 = equals, +1 = greater
    - Code block return value used for comparisons

Ruby Summary

- Interpreted
- Implicit declarations
- Dynamically typed
- Built-in regular expressions
- Easy string manipulation
- Object-oriented
  - Everything (!) is an object
- Code blocks
  - Easy higher-order programming!
  - Get ready for a lot more of this...

Makes it quick to write small programs

Hallmark of scripting languages

Other Scripting Languages

- Perl and Python are also popular scripting languages
  - Also are interpreted, use implicit declarations and dynamic typing, have easy string manipulation
  - Both include optional "compilation" for speed of loading/execution
- Will look fairly familiar to you after Ruby
  - Lots of the same core ideas
  - All three have their proponents and detractors
  - Use whichever language you personally prefer

Example Perl Program

```
#!/usr/bin/perl
foreach (split//, $ARGV[0])) {
  if ($G{$_}) {
    $RE .= "\\" . $G{$_};
  } else {
    $RE .= $N ? "(?!\\" .
  join("|\\",values(%G)) . ')(\w)' : '(\w)';
    $G{$_} = ++$N;
}  }
```

Example Python Program

```
#!/usr/bin/python
import re
list = ("deep", "deer", "duck")
x = re.compile("^\S{3,5}.[aeiou]")
for i in list:
  if re.match(x, i):
    print I
  else:
    print
```